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Report on the First NSF CubeSat Software Research Experience for Undergraduates

Jeremy Straub

Department of Computer Science, North Dakota State University
1320 Albrecht Blvd., Room 258; Fargo, ND 58102; 701-231-8196
jeremy.straub@ndsu.edu

ABSTRACT

For three summers, 2015, 2016 and 2017, undergraduate students from around the United States came to North Dakota to participate in a NSF sponsored Research Experience for Undergraduates program focused on CubeSat software. This program was the first NSF-sponsored Research Experience for Undergraduates program focused on CubeSat software. This paper presents the final results from all three years of that program.

INTRODUCTION

Small satellite programs provide students with numerous benefits including the opportunity to have hands-on access to spacecraft hardware. Building on the benefits enjoyed by numerous programs nationwide, a program was created to provide software-related research experiences to undergraduate students.

Software is an area of growing importance for spacecraft as computational capabilities improve, enabling numerous novel mission types that were previously impractical or impossible. Software-driven missions [1], [2] are currently possible and the use of federated systems [3]–[5] is poised to provide significant benefits now and in the future. Because of these and other similar developments (including similar mission concepts in the UAV space), having a workforce skilled in the development of aerospace software is critical.

Between 2015 and 2017, undergraduate students came to North Dakota to participate in a Research Experience for Undergraduates (REU) program focused on CubeSat software. This paper presents the results from all three years of that program.

First, it provide a brief background on small satellites and previous work related to their educational and other uses. Next, the characteristics of the participants in the three years of the REU are presented and discussed. Then, focus turns to the benefits that the participants enjoyed from participation. Specifically, their pre- and post-participation levels of several characteristics are presented and compared, for each program year.

Following this, the participants' beliefs about the attribution of the gains that have been identified are examined. Participants were asked to indicate their level of agreement with the attribution of

enhancements in each area to program participation and these results are presented. Finally, the paper concludes with a discussion of what has been discussed and related future work.

BACKGROUND

Small spacecraft are commonly used for educational purpose [6], [7] and they are increasingly gaining use for commercial [8], governmental [9] and military uses [10]–[12], as well. Previous work has discussed the benefits of small satellites, in general [13] as well as the impact undergraduate student research experiences related to this topic [14].

An extended discussion of the benefits of project-based learning and small spacecraft can be found in [6], [7]. Details regarding student expectations and their attainment are discussed in [15], [16]. The efficacy of undergraduate student small spacecraft research is considered in [17] and specific program impact in computing is discussed in [18]. More details about launching an assessing small spacecraft programs can be found in [19].

ABOUT THE PARTICIPANTS

The REU participants, over the course, of the three years came from a wide variety of locations and backgrounds. Student participants included a mix of individuals from research universities as well as non-research four year colleges and universities and community colleges.

The participants all had completed at least a semester of college before attending the program. Several were entering their fifth year as a 'super-senior'. Figure 1 depicts the breakdown of the participants' class in school by REU year.

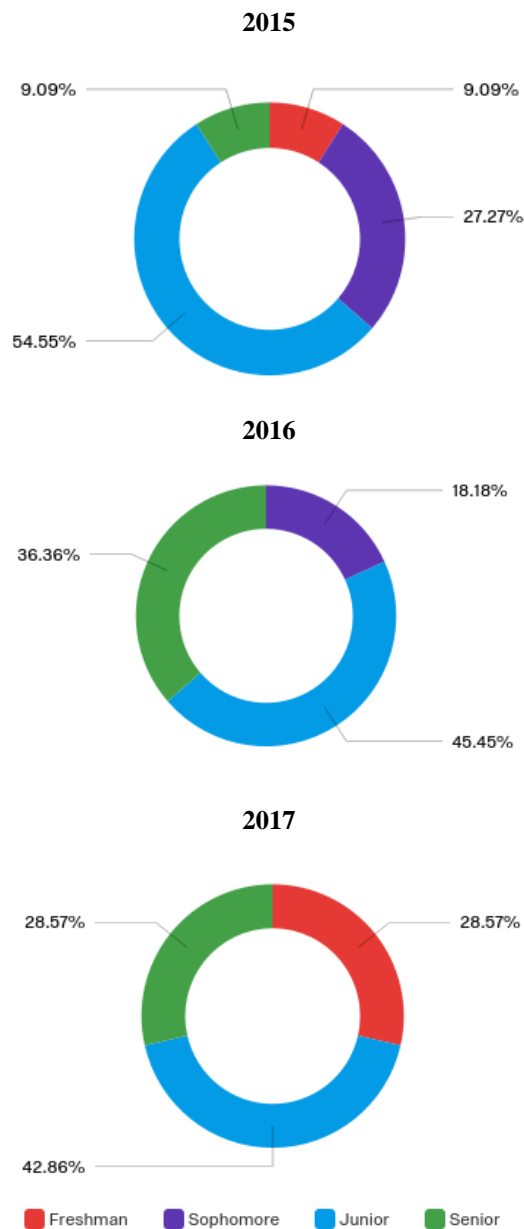


Figure 1. Participants Class Year, by Program Year.

The participants' grade point average (GPA) was a screening criteria for applicants. However, other factors were also considered. Most participants had a GPA between 3.5 and 4.0. Figure 2 depicts the participants' GPA by program year.

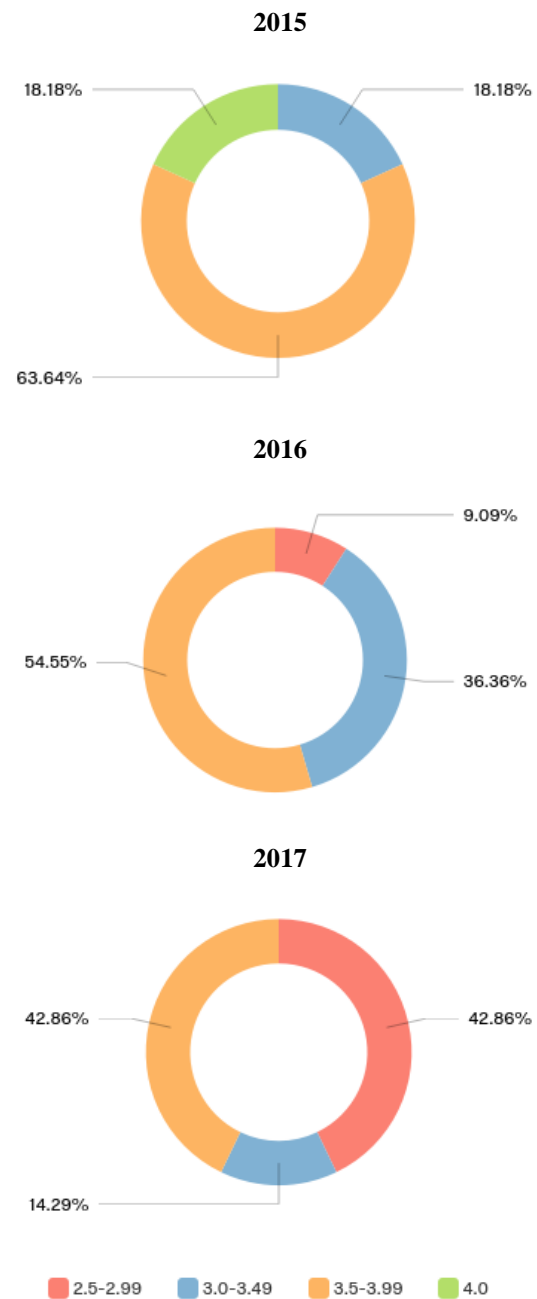


Figure 2. Participants GPA, by Program Year.

Participants were asked why they decided to apply to the program and participate. The technical area of participation, excitement about space and spacecraft and resume benefits were all frequently indicated by participants. Participants were also given the ability to write in other responses. These included the program's trips to visit a NASA facility and missile silo and working with actual spacecraft hardware and software. Being mentored on a spacecraft project was also mentioned by one participant. Figure 3 depicts the breakdown of reasons for participation selected, by program year.

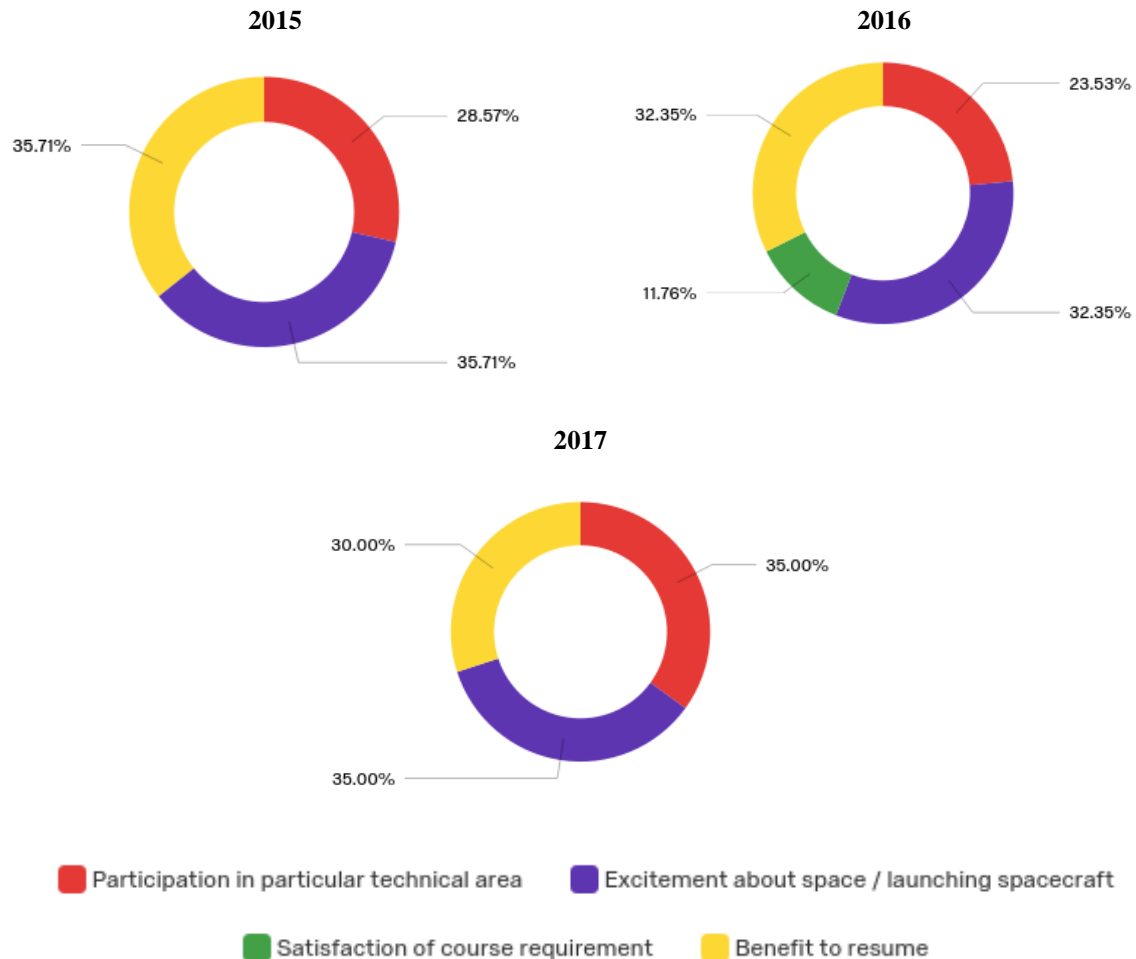


Figure 3. Reason for Participation, by Program Year.

IMPACT OF PARTICIPATION

To assess the benefits of participation, participants were asked to indicate their pre-participation and post-participation status levels in regards to a variety of areas. Both pre- and post-participation level data were collected from participants at the conclusion of participation, as otherwise changes in the participants perception of the status levels themselves would be a confounding variable. Figure 4 indicates participants' pre- and post-participation technical skill levels, in their area of participation. A notable improvement is shown in each of the three years.

Data was also collected regarding the participants' skill and comfort level in spacecraft design. Figure 5 indicates how many of the participants had previous spacecraft experience (most did not) and where that experience originated from. Figure 6 indicates participants' pre- and post-participation spacecraft design skill levels. Figure 7 indicates participants' pre- and post-participation spacecraft design comfort levels. Clear improvement in spacecraft design skills is shown each year.

Improvement in spacecraft design comfort is also indicated.

Participants were also asked to indicate their levels of excitement about space. Figure 8 depicts participants' pre- and post-participation space excitement levels. These started relatively high, with nearly everyone initially being above 'somewhat excited'. No significant increase is evident in space excitement and years 1 and 2 show a minor decrease.

Participants were asked to indicate their pre- and post-participation levels of presentation skills and comfort. Figure 9 depicts the changes in presentation skill levels and Figure 10 depicts the changes in presentation comfort levels. Moderate improvement in each area was shown in each of the three years.

Participants were asked to indicate their pre- and post-participation levels of leadership skill and leadership confidence. Figure 11 depicts leadership skill level change and Figure 12 depicts leadership confidence level change. Again, a moderate level of

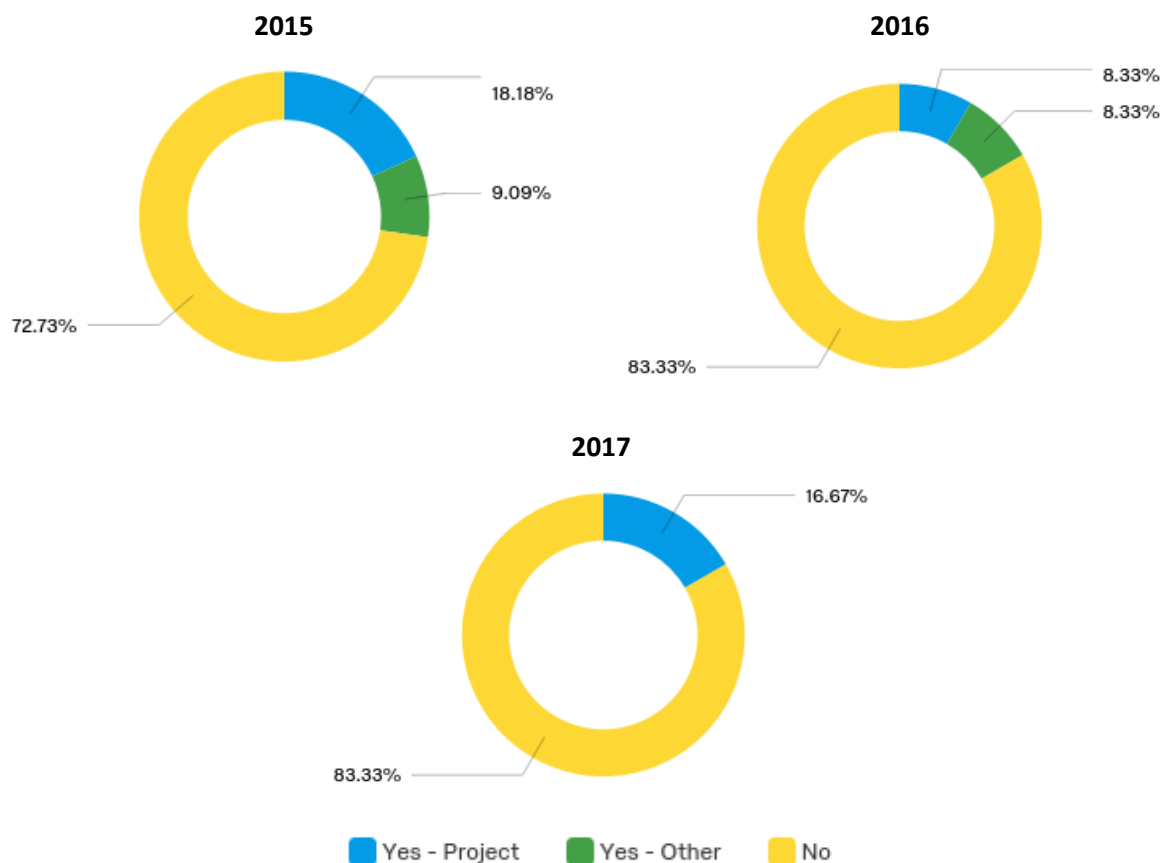


Figure 4. Previous Spacecraft Experience, by Program Year.

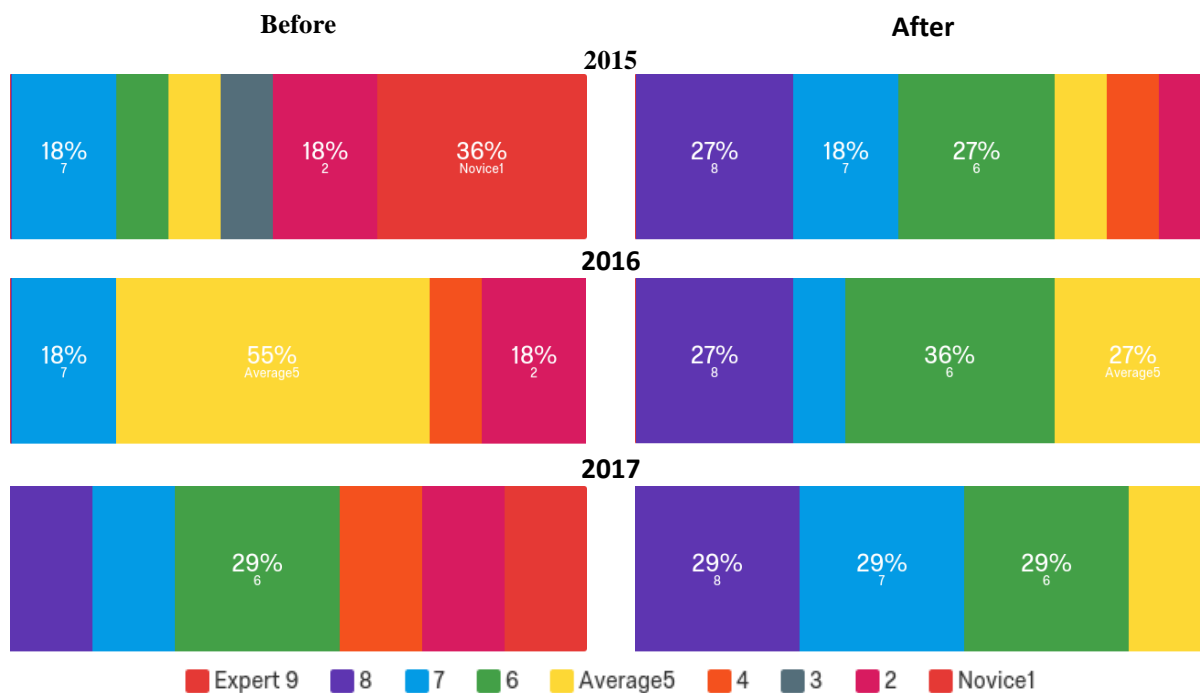


Figure 5. Spacecraft Design Skill, by Program Year.

improvement was shown in each of the four program years.

Finally, participants were asked to indicate their pre- and post-participation levels of project management

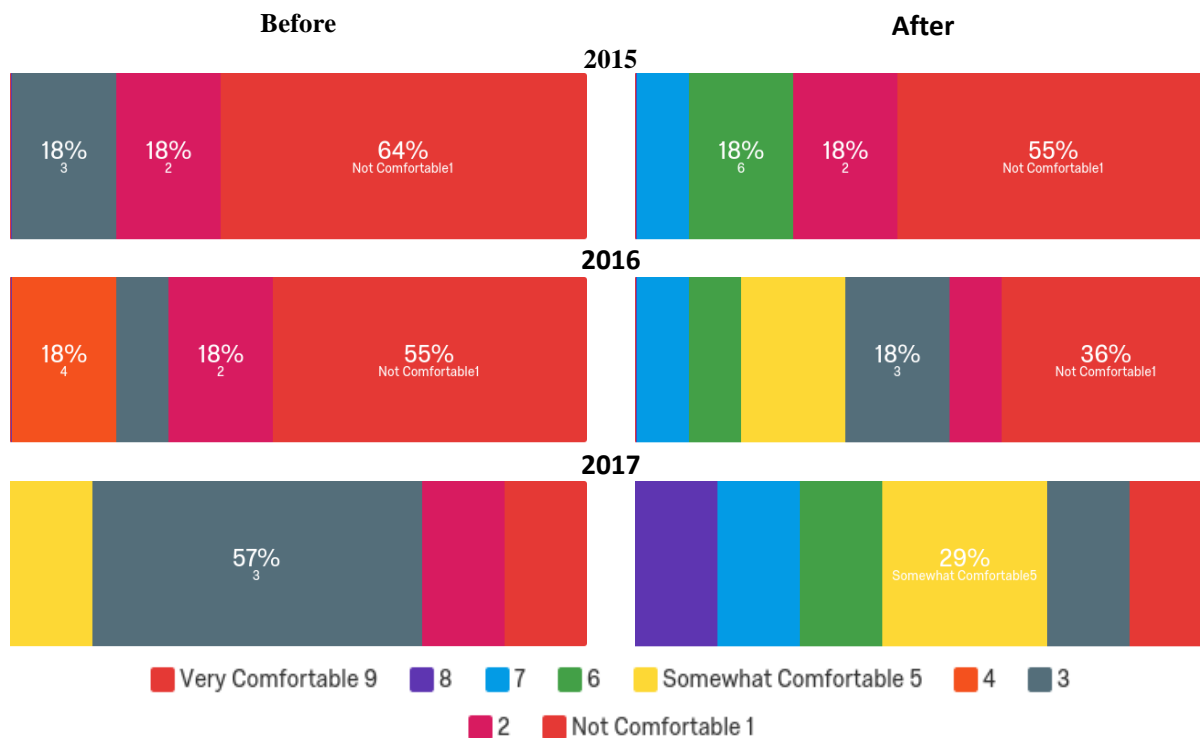


Figure 5. Spacecraft Design Comfort, by Program Year.

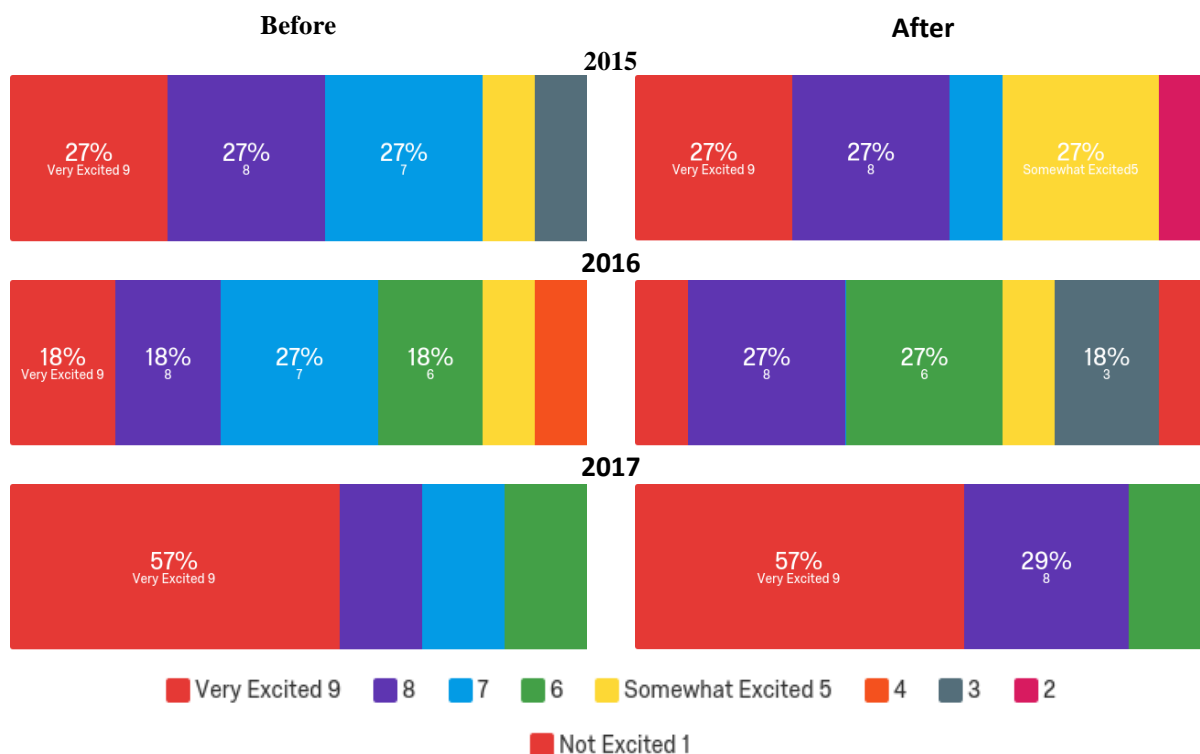


Figure 6. Space Excitement, by Program Year.

skill and time management skill. Figure 13 depicts project management skill level changes. Figure 14 depicts time management skill level changes. Moderate improvement is shown in all four years, though notably, in year 3, some participants reported

a slightly lower post-participation skill level than their pre-participation skill level.

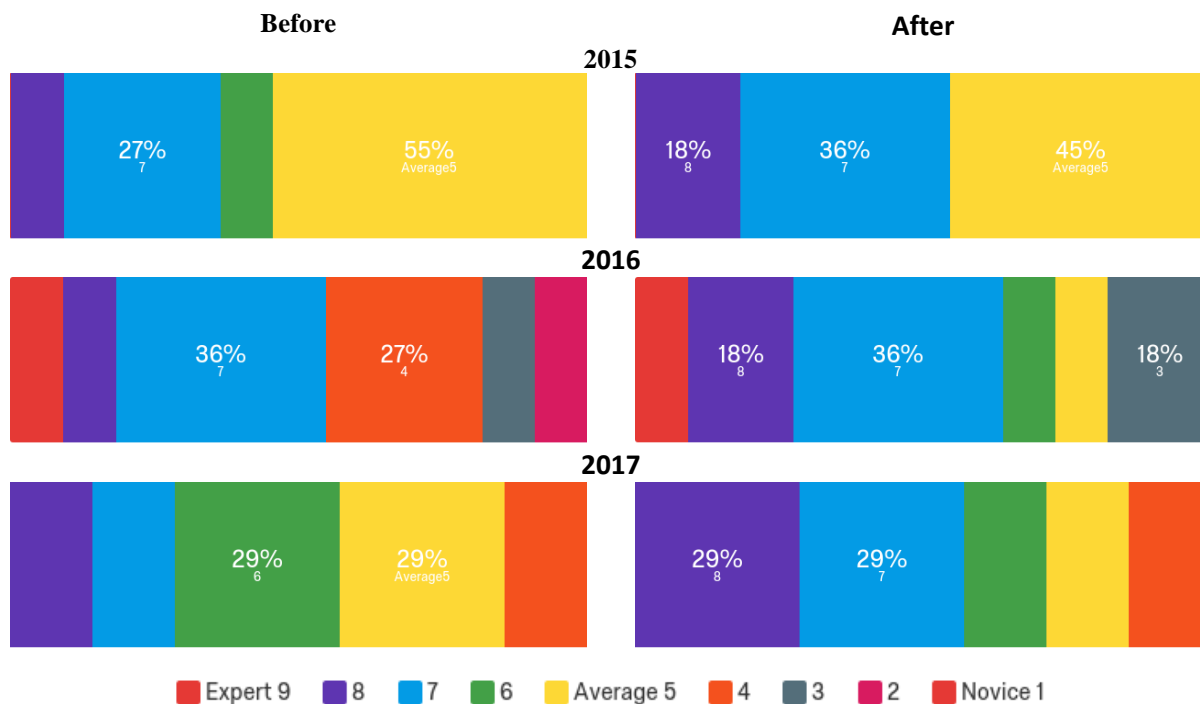


Figure 7. Presentation Skills, by Program Year.

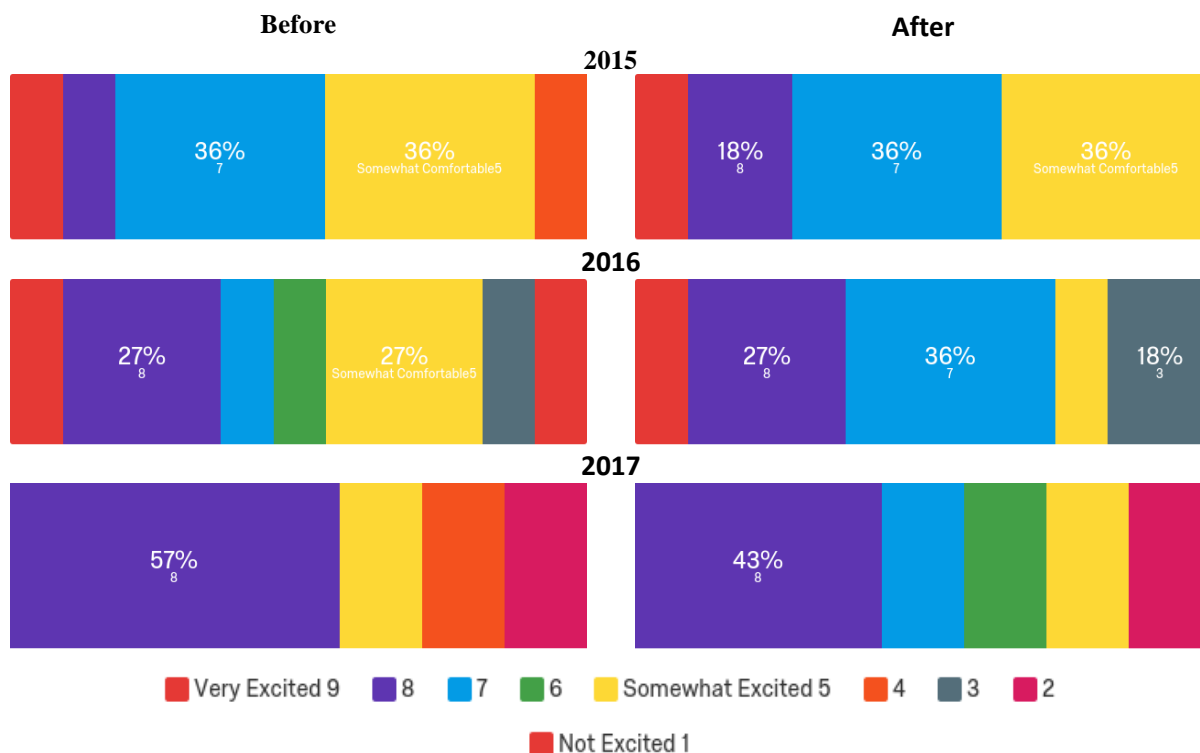


Figure 8. Presentation Comfort, by Program Year.

BENEFIT PARTICIPATION ATTRIBUTION

Participants were also asked questions to indicate whether they attributed the benefits that they received to their participation. Figure 13 to 21

depict the attribution of the attainment of each type of benefit to program participation.

Figure 13 depicts the attribution of improved technical skills, in the area of participation, to the

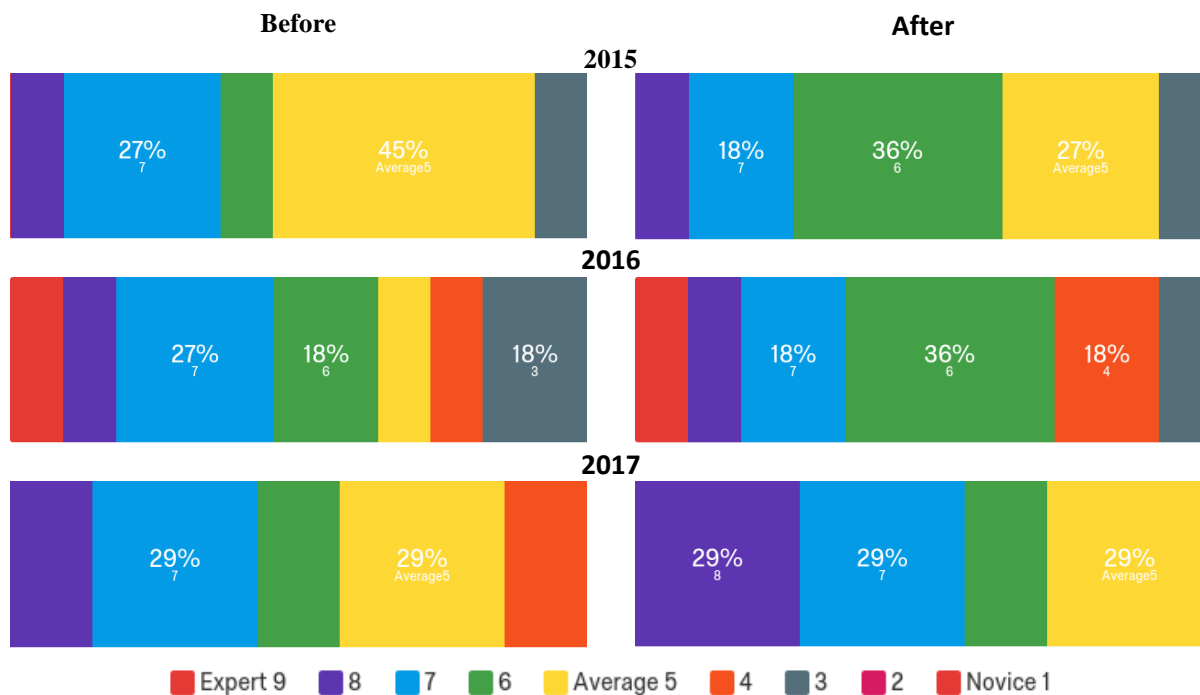


Figure 9. Leadership Skills, by Program Year.

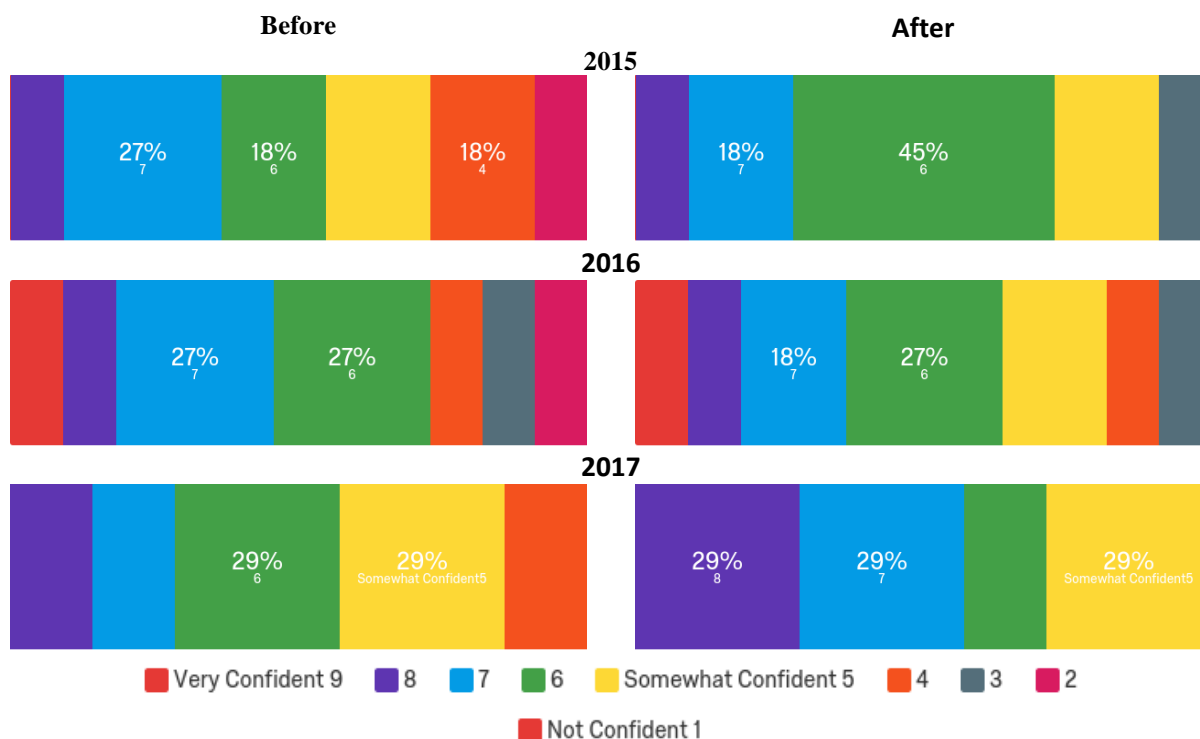


Figure 10. Leadership Confidence, by Program Year.

program. Figure 14 presents that attribution of improved interest in space to participating in the program. Figure 15 presents data relating to the program's impact on improved presentation skills. Figure 16 presents attribution data for improved presentation comfort. Figure 17 depicts the

attribution of the impact of the program on project management skills. Similarly, Figure 18 presents attribution data related to project management confidence. Next, Figures 19 and 20 present attribution data for improved leadership skills and confidence, respectively. Finally, Figure 21

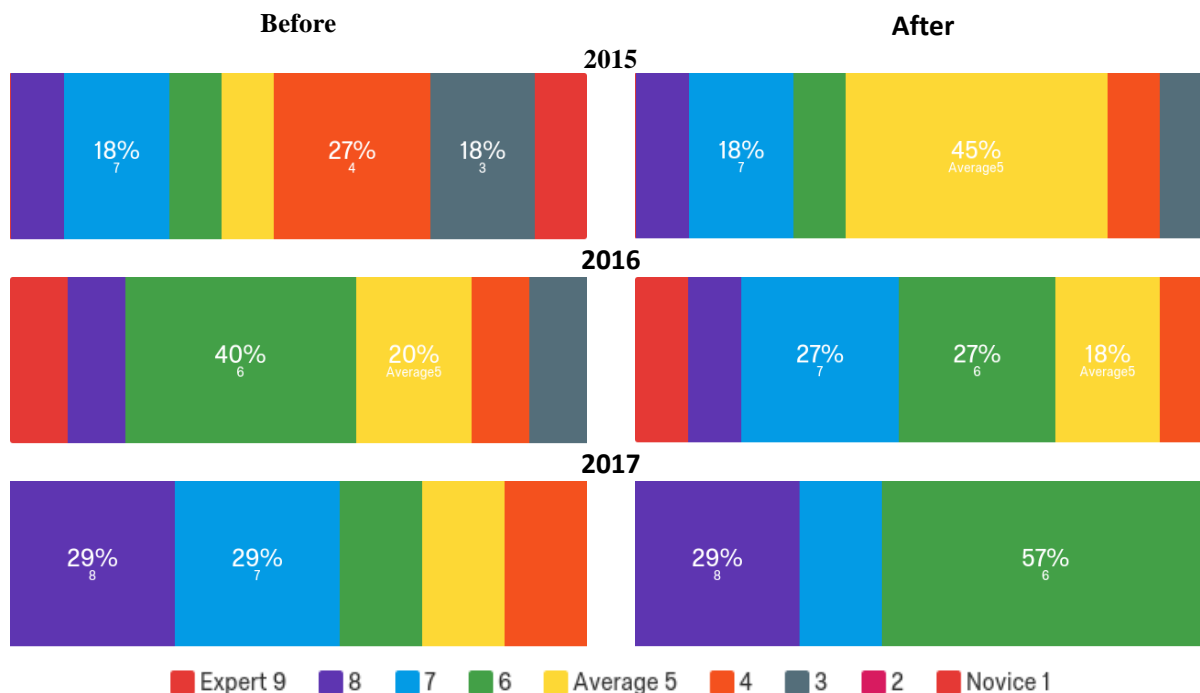


Figure 11. Leadership Skills, by Program Year.

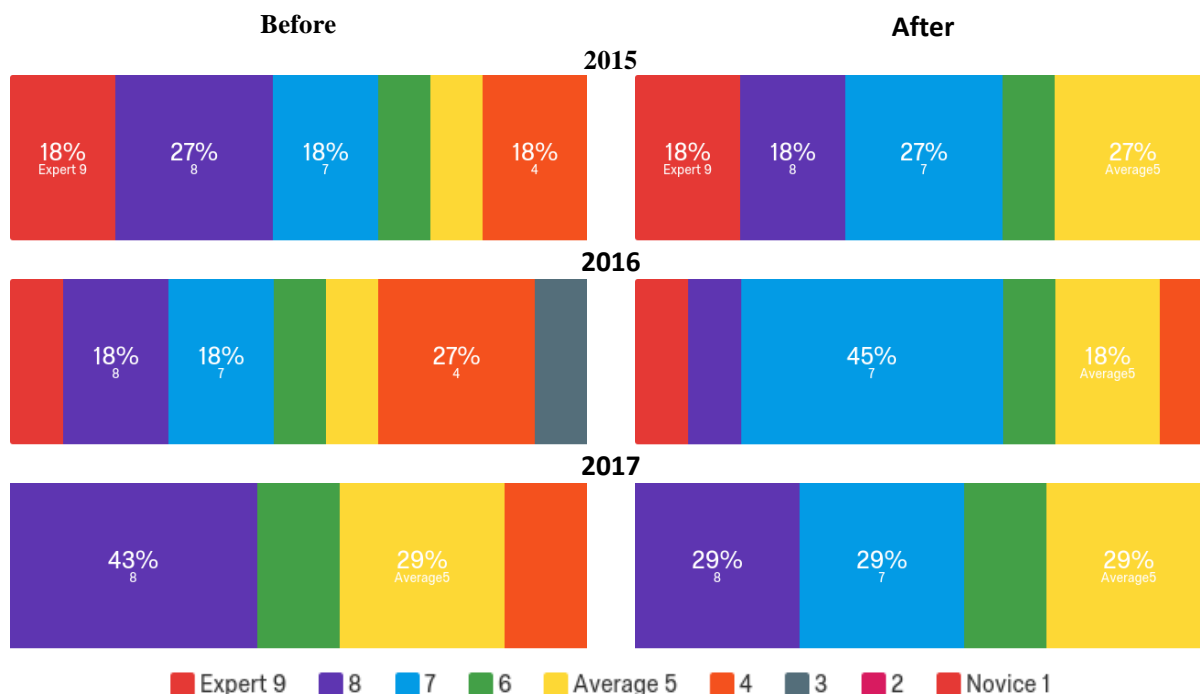


Figure 12. Time Management Skills, by Program Year.

presents data related to participants attributing enhancements in their time management skills to participating in the undergraduate research program.

CONCLUSIONS & FUTURE WORK

This paper has presented data related to all three years of the operations of the NSF and Department

of Defense supported Research Experience for Undergraduates program at the University of North Dakota. It has compared the data between each of the three years.

Ongoing work relates to the further analysis of this data set and, in particular, its comparison to national survey data. Future work will also include the

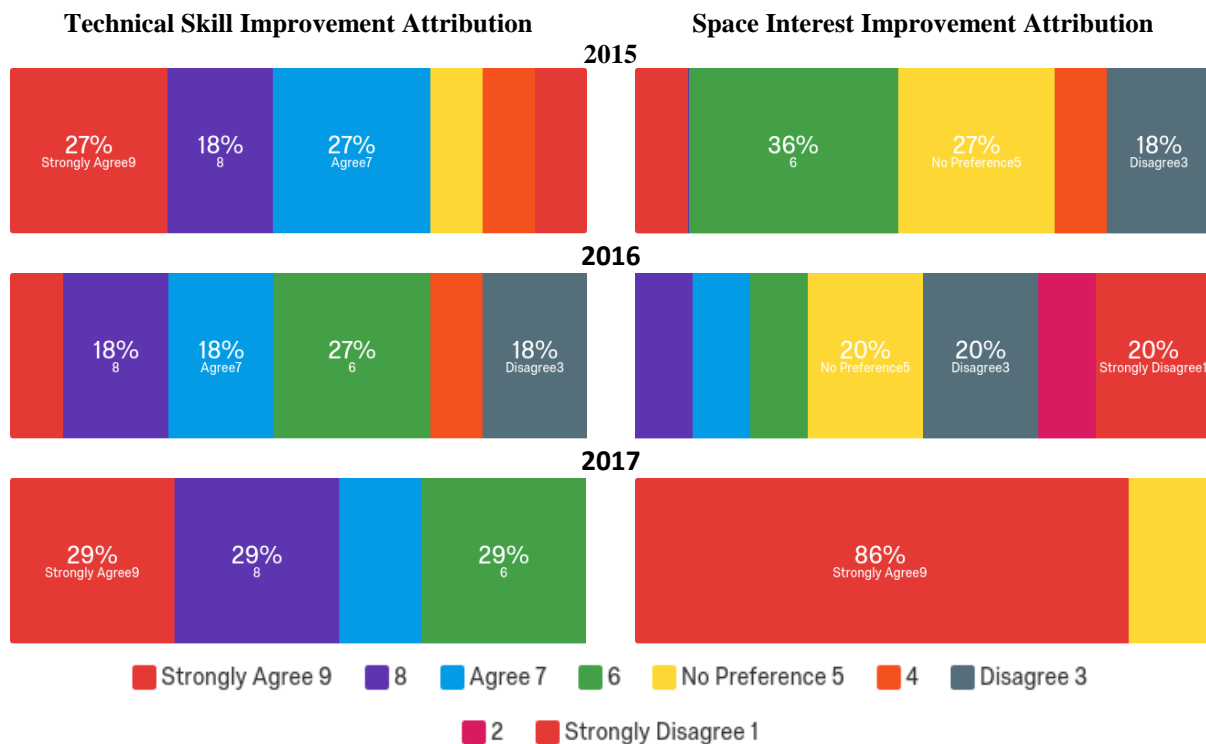


Figure 13. Technical Skill and Space Interest Improvement Attribution, by Program Year.

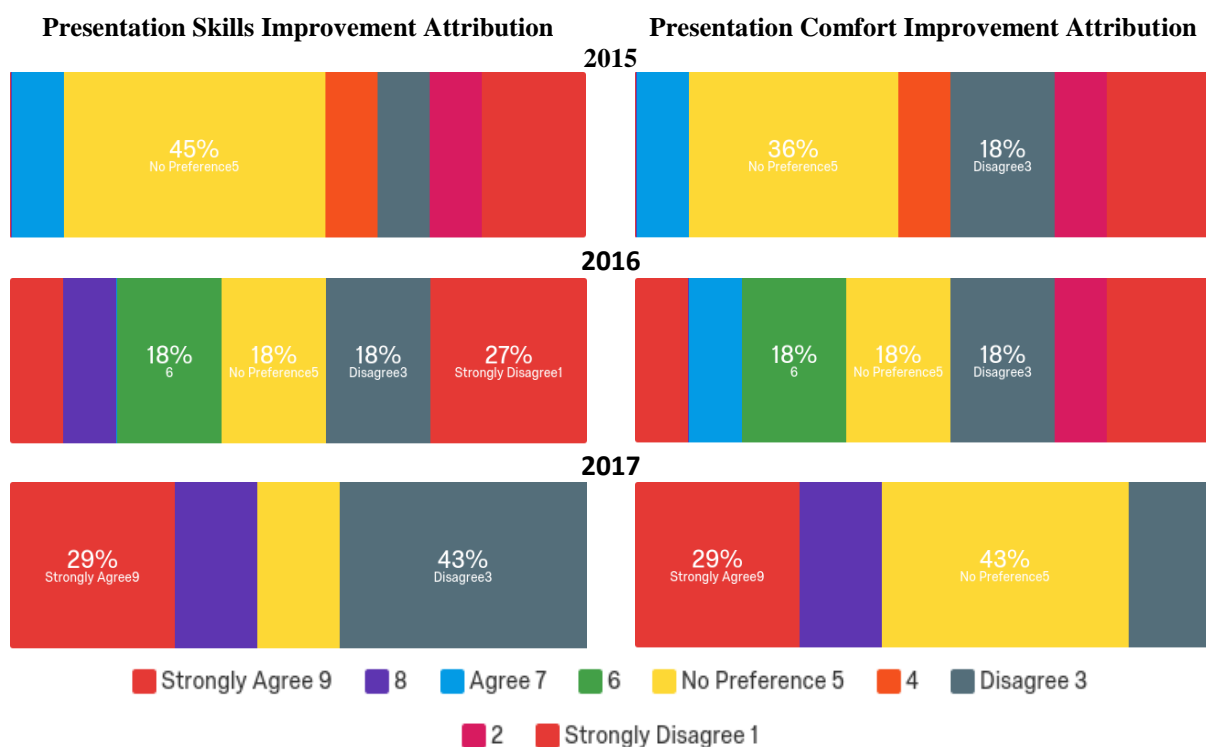


Figure 12. Presentation Skills and Comfort Improvement Attribution, by Program Year.

comparison of this data to the performance of other undergraduate research programs.

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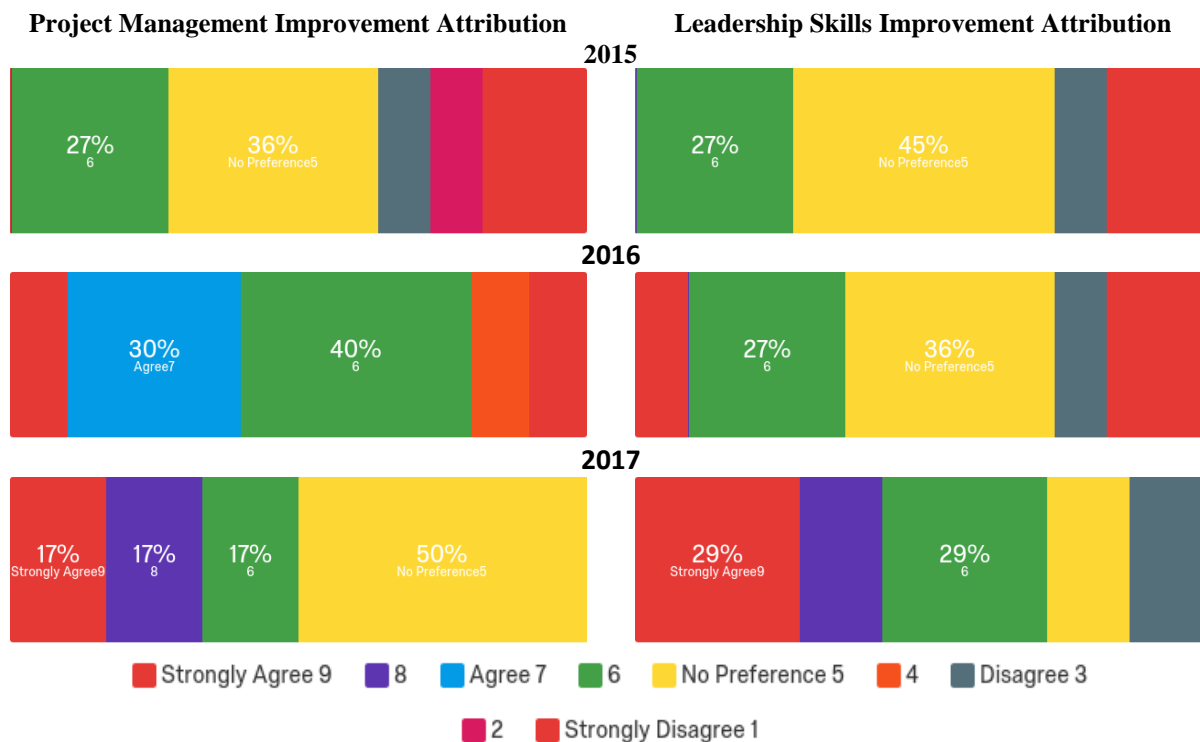


Figure 13. Project Management and Leadership Skill Improvement Attribution, by Program Year.

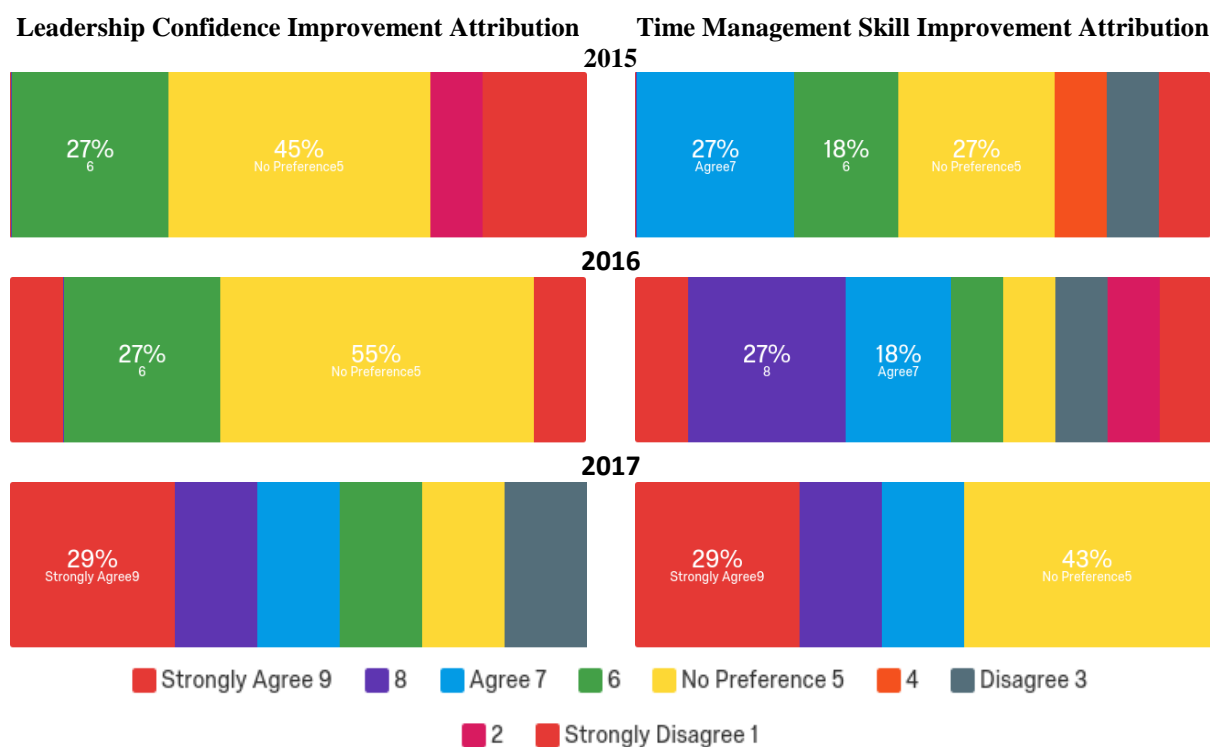


Figure 12. Presentation Skills and Comfort Improvement Attribution, by Program Year.

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